University of Technology, Sydney
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INNOVATIVE PRODUCT DESIGN CONCEPTUALIZATION WITH OIL-LESS TWO-STROKE ENGINE AS A CASE STUDY

by

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I wish to dedicate this to my parents,

Manfred and Ellen Roser,

whose kindness, support, and care I am forever grateful.

CERTIFICATE OF ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

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GLOSSARY AND NOTATIONS

ACE	Active Combustion Engine
AI	Artificial Intelligence
ATAC	Active Thermo-Atmosphere Combustion
BDC	Bottom Dead Centre
CA	Customer Attributes
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Process Planning
CBR	Case Based Reasoning
CCES	Concept Classification and Evaluation Scheme
CE	Concurrent Engineering
CFD	Computational Fluid Dynamics
CI	Compression Ignition
CIM	Computer Integrated Manufacturing
CL	Complexity Level
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPM	Critical Path Method
DBD	Decision Based Design
DCDI	Determination of Critical Design Issues
DFA	Design for Assembly or Design for Affordability
DFC	Design for Cost
DFD	Design for Disassembly
DFM	Design for Manufacturing or Design for Maintenance
DFR	Design for Recycling
DFS	Design for Serviceability or Design for Simplicity
DFX	Design for X
DI	Direct Injection
DoE	Design of Experiments

DP	Design Parameters
DR	Delivery Ratio
ECU	Engine Control Unit
EED	Early Empirical Design
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency (US)
EU	European Union
FEA	Finite Element Analysis
FR	Functional Requirements
FSI	Fuel Stratified Injection
GA	Generic Algorithm
GDI	Gasoline Direct Injection
HC	Hydrocarbons
HCCI	Homogeneous Charge Compression Ignition
IC	Internal Combustion
ICD	Innovative Conceptual Design
IDI	Indirect Injection
LPG	Liquefied Petroleum Gas
MADM	Multiple Attribute Decision Making
ML	Maturity Level
MODM	Multiple Objective Decision Making
MON	Motor Octane Number
NO_x	Nitrogen Oxides
NPD	New Product Development
OCP	Orbital Combustion Process
PA	Problem Analogy
PC	Problem Complexity
PEEK	Polyetheretherketone
PERT	Program Evaluation and Review Technique
PF	Problem Familiarity
PDS	Product Design Specification
PM	Particulate Matter
PR	Purity Ratio

PTFE	Polytetrafluoroethylene
PV	Process Variables
QFD	Quality Function Deployment
R&D	Research and Development
RC	Relative Cost
RL	Risk Level
RON	Research Octane Number
RSM	Response Surface Methodology
SI	Spark Ignition
SiC	Silicon Carbon
SO_2	Sulphur Dioxide
TDC	Top Dead Centre
TIAE	Technology Identification, Analysis, and Evaluation
TRIZ	Teoriya Resheniya Izobreatatelskikh Zadatch (Theory of Inventive Problem Solving)
US	United States
UTS	University of Technology, Sydney
VA	Value Analysis
VE	Value Engineering
VDI	Verein Deutscher Ingenieure
WOIS	Widerspruchsorientierte Innovationsstrategie (Contradiction Oriented Innovation Strategy)
WOT	Wide Open Throttle

SYMBOLS

B	Cylinder Bore
S	Piston Stroke
S_{ec}	Effective Compression Stroke
S_{ee}	Effective Expansion Stroke
a	Crank Offset
r_{sb}	Stroke-to-Bore Ratio
V_d	Displacement Volume
V_{dec}	Effective Compression Displacement Volume
V_{dee}	Effective Expansion Displacement Volume
V_c	Clearance Volume
V_t	Total Cylinder Volume
A_p	Piston Crown Surface Area
A_h	Cylinder Head Surface Area
A_t	Total Cylinder Surface Area
r_c	Compression Ratio
r_{gc}	Geometric Compression Ratio
r_{ec}	Effective Compression Ratio
r_{ee}	Effective Expansion Ratio
φ	Crank Angle
N_c	Rotational Speed of Crank
ω_c	Angular Velocity of Crank
v_{pm}	Mean Piston Velocity
n_r	Number of Crank Revolutions per Cycle
p_{ct}	Cylinder Pressure at TDC
p_{cs}	Cylinder Pressure after Scavenging
A/F	Air/Fuel Ratio
$m*_a$	Mass Flow Rate of Air
$m*_f$	Mass Flow Rate of Air
Q_{hvl}	Lower Heating Value
Q_a	Heat Addition

z_φ	Cumulative Heat Release Fraction
n	Weibe Form Factor
a	Weibe Efficiency Factor
P	Power Output
T	Torque or Temperature
mep	Mean Effective Pressure
$imep$	Indicated Mean Effective Pressure
$bmep$	Brake Mean Effective Pressure
$fmep$	Friction Mean Effective Pressure
sfc	Specific Fuel Consumption
η_{th}	Thermal Efficiency

ABSTRACT

Innovative Product Design Conceptualization with Oil-Less Two-Stroke Engine as a Case Study

Innovative product design is a creative process, involving extensive skills and knowledge, numerous stakeholders with often conflicting interests, and a variety of trade-off decisions. The multitude of different variables to be considered together with the complex nature of engineering design confronts designers with a difficult challenge.

The objective of this thesis is to establish a methodology that will help to formalise and enhance innovative conceptual product design. To achieve this, an oil-less two-stroke engine concept has been taken as a case study in order to elaborate, demonstrate, and validate the proposed *Innovative Conceptual Design* framework. The methodology aims to yield design process insight and transparency, and embodies two major phases: the *Pre-Development* activities, including the identification of need and product definition, and the *Conceptualization Loop*, which comprises the determination of attributes, concept generation, concept evaluation, and concept decision.

In this present research, the *Determination of Critical Design Issues* together with *Early Empirical Design* are identified as two essential aspects of successful conceptual design. Early detection of potential design problems is vital for making intelligent and rapid concept decisions before significant development resources are committed. This approach also allows critical design issues to be tackled first in order to avoid going down blind alleys, and helps to control risk and cost.

The thesis presents the author's view of conceptual design as involving a continuous focus on four major pillars of design, namely the *Time Focus*, the *Innovation Focus*, the *Cost Focus*, and the *Simplicity Focus*, the "TICS Focuses". On the basis of this perception the discrete design activities during the entire design process aim to develop an innovative, inexpensive, and simple product that is introduced to the marketplace in a timely manner. This may require the designer to make a number of compromises, which can be facilitated by the early detection of design problems by means of Early Empirical Design.

In essence, the suggested conceptual design framework supports design engineers in making issues and problems obvious in the early, least-costly phases of product development. This is the key to accelerating the overall design process and avoiding product failures.